Earth Science Enterprise Technology Planning Workshop

Laser Technology

James Spinhirne (GSFC) - Co-Chair
Upendra Singh (LaRC) - Co-Chair
Robert Menzies (JPL) - Facilitator

23-24 January 2001

Laser Technology

Agenda

Tuesday, Jan 23, 2001

- Future Directions in Laser Altimeter Measurements of the Earth's Surface - David Harding, NASA GSFC
- Global Carbon Cycle Sources and Sinks - Donald J. Wuebbles, Department of Atmospheric Sciences, University of Illinois
- Lidar profiling of ozone and water vapor from space - Syed Ismail and E. V. Browell, NASA LaRC
- Review of Approaches to Doppler Wind Lidars - Dave Emmitt, Simpson Weather Associates
- Laser requirements and design for space - Robert Afzal, NASA GSFC
- Challenges in Laser Technology for NASA Applications - T. Y. Fan, MIT Lincoln Laboratory
- Lasers For Remote Sensing Of Planet Earth - Norman P. Barnes, NASA LaRC
- Solid-State Laser and Laser Diode Arrays Technologies and Challenges - Mark Kushina, Cutting Edge Optronics
- Recent Development of an Eye-Safe 2-µm Laser- Jirong Yu and Upendra N. Singh, NASA LaRC
- Laser Measurement of Atmospheric CO2 - Jim Abshire, NASA GSFC
- Rare-Earth-Doped Fiber Lasers and Amplifiers for Chemical Sensing in the IR and UV - Dahv A.V. Kliner, Sandia National Laboratories, Jeffrey P. Koplow, and Lew Goldberg, Naval Research Laboratory
- UV and Eye-Safe IR High-Power Diode-Pumped Raman Lasers for Space Applications - G. Pasmanik, Passat Ltd, and A. E. Dudelzak, Canadian Space Agency
- Photon-Counting Imaging Microlaser Altimeters - John J. Degnan, NASA GSFC
- Diode Laser Stabilization for Optical Metrology An Optical Atomic Clock in Support of Time-Varying Gravity-Mapping Missions - William M. Klipstein, David J. Seidel, John A. White, and Brenton C. Young, JPL

Laser Technology

Agenda

Wednesday, Jan 24, 2001

- Laser/Lidar Technology Roadmap and Validation - Frank Peri, Earth Sciences Technology Office, NASA GSFC
- Identify convergence of Science needs and candidate Technology approaches
  - new capabilities enabled
  - reductions in implementation and life-cycle costs
- Define specific capability/technology needs for each measurement class
- Describe and illustrate the current state of the art for the technology
- Itemize the major technology components and current technology readiness level
- Identify ongoing investments
- Identify technology development gaps
- Delineate core technology development and risk reduction plan
- Emphasize laser transmitter subsystem development to EM-level for risk reduction purposes
- Identify schedule and cost data for brassboard and engineering model development of laser subsystems for science-driven missions
  - Show key laser technology classes needed for science mission types
  - Identify laser transmitter parameters required
    - Associate schedule and cost estimates for brassboard/EM development/testing
- Summary Plenary Session

Workshop Participants

G.D. Emmitt	SWA/UVA
Syed Ismail	LaRC
Brad Greeley	Orbital
Dahv Kliner	Sandia Nat'l Labs
Bruce Gentry	GSFC
John Degnan	GSFC
Guerman Pasmanik	Passat Ltd.
Joanne Hopkins	SRI Int'l
Ben Barker	LaRC
John Burris	GSFC
Floyd Hovis	Fibertek
Tony Grillo	ESTO
Charles F. Bruce	MIT Lincoln Lab
T.Y. Fan	MIT Lincoln Lab
Renny Fields	Aerospace Corp
Robert Afzal	GSFC
Brenda S. Smith	NMOC/Stennis SC
Alex Dudelzak	Canadian Space Agency
Stan Schneidet	NPOESS/NASA
Brian Killough	NASA LaRc
Jeff Mirick	NIMA/ATTR
Bob Schutz	U of TX
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Don Wuebbles	U of IL
David Olson	ITT
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Jirong Yu	LaRC
Jim Abshire	GSFC
Tom McGee	GSFC
Prabharar Misra	Nat'l Academy of Science
Bill Heaps	GSFC
John Brock	TRW
Marc A. Mogavero	Northrop
Norman Barnes	LaRC
Michael J.Kavaya	LaRC
Timothy D. Cole	APL
Ron Ticker	NASA HQ
David Harding	GSFC

Laser Technology

Component Technologies

Quasi-CW Laser Diode Arrays
- High power (~200 W) conduction-cooled
- High brightness, high temperature LDA's
- High electrical-to-optical efficiency
- 5-years lifetime

Robust Optical Components and Coatings
- High damage threshold
- Thermal and Radiation Tolerance

Heat Pipe Technologies for Thermal Management

Efficient Long-life Driver Electronics

Measurement Approach
- Scanning Lidar Altimetry
- Differential Absorption Lidar
- Doppler Lidar

Science Needs
- Ice sheet and terrain monitoring
- Biomass Measurement
- Tropospheric Chemistry
- Tropospheric Winds
- Global Carbon Dioxide
- Cloud/Aerosol Radiative Forcing

Development Plans for Altimetry Laser Transmitter

Laser Type

- Nd:YAG high PRF (>1000 Hz),
  - Single mode,
  - Narrow frequency,
  - 5-20 Watts Output
- Micro-chip or fiber laser alternative
  - PRF>10 kHz
- 3-5 years lifetime
- Wavelength: not critical, ideally near-IR

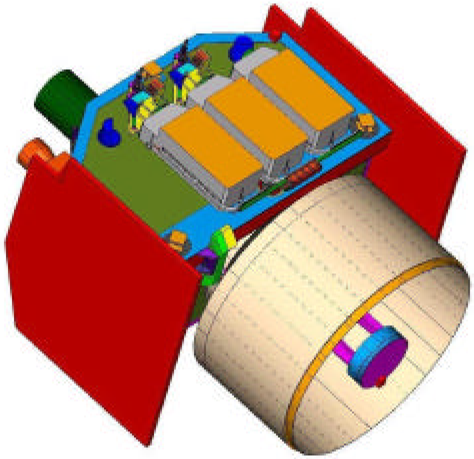
Justification

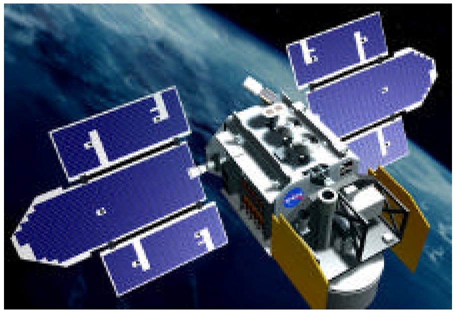
- Enables scanning altimetry lidar
  - Ice Sheet Change
  - Vegetation Recovery
  - Terrain Mapping
  - Cloud/Aerosol Height Profiling

Top-Level Development and Schedule

- Component development 2002-2003
  Brassboard 2003-2004
  Engineering Model 2004-2006


GLAS Nd:YAG Laser

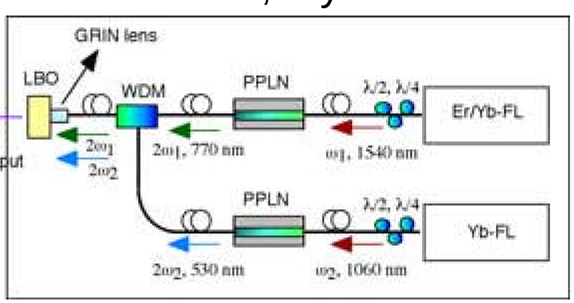


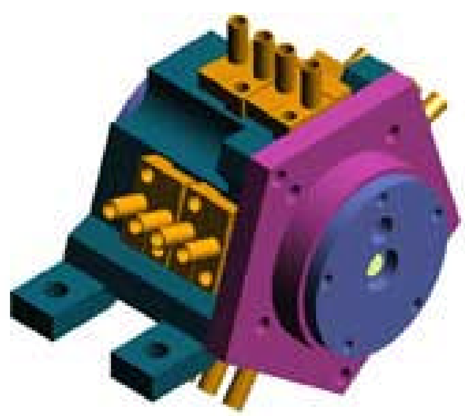


Development Plans for Tropospheric Chemistry Laser Transmitters

Laser Type

- UV Ozone DIAL
  - 305/320 nm wavelength pair
  - 0.5-1J at 5-20 Hz doubled pulse
  - 50 pm linewidth
  - WPE 1%, 3 years lifetime
- IR Ozone DIAL
  - 9.5 micron CO_2 laser
  - 250 mJ @ 100 Hz
  - Frequency agile
  - WPE 15%, 3 years lifetime
- IR Water Vapor DIAL
  - 940 or 1100 nm tunable wavelength pair
  - 0.5-1J at 10 Hz doubled pulse
  - 0.25 pm linewidth,
  - Spectral purity > 99%
  - WPE 2%, 3 years lifetime



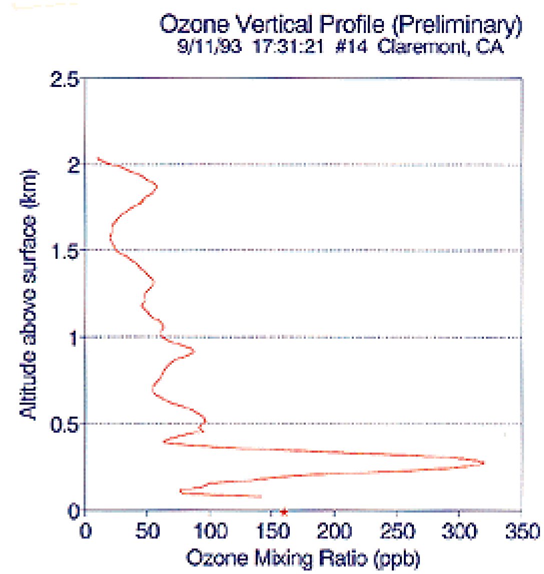


Justification

•Enables high vertical resolution profiling of
  - Tropospheric Ozone
  - Tropospheric Water Vapor

Top-Level Development Schedule

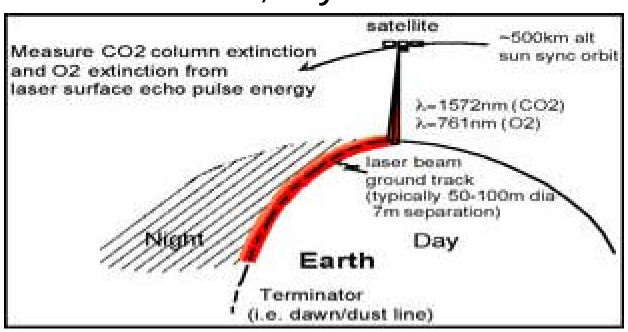
- Component development 2002-2003
- Brassboard 2003-2004
- Engineering Model 2004-2006



Development Plans for Tropospheric Carbon Dioxide Laser Transmitters

Laser Type

- Integrated Path Differential Absorption (IPDA)
  - 1.6 µm wavelength pair, tunable
  - “Reference” transmitter at 761 nm (1 mJ)
  - 10 mJ at 4 kHz, 1-10 microsec pulsewidth
  - 3 MHz linewidth
  - WPE 8% (goal), 3 years lifetime
- Integrated Path Differential Absorption (IPDA)
  - 2.05 µm wavelength pair, tunable
  - 3-5 W CW ; 3 MHz linewidth
  - WPE 3%, 3 years lifetime
- DIAL
  - 2.05 µm, tunable wavelength pair
  - 1-2 J at 5-20 Hz, double-pulse
  - conductive-cooling
  - 3 MHz linewidth
  - WPE 2%, 3 years lifetime



Justification

- Enables ultra high precision profiling of tropospheric carbon dioxide:
  - IPDA with tunability achieves 2-3 km vertical resolution in lower troposphere
  - DIAL with range-gating achieves 1 km vertical resolution in lower troposphere and inherent cloud/aerosol profiling

Top-Level Development Schedule

IPDA Approaches:

- Component development 2002
- Brassboard 2003
- Engineering Model 2003-2004

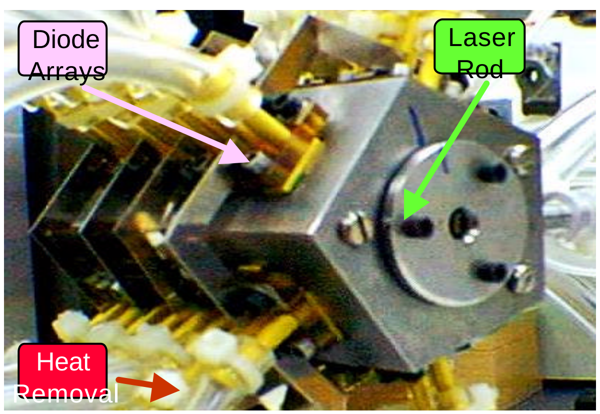
DIAL:

- Component development 2002-2003
- Brassboard 2003-2004
- Engineering Model 2004-2006

Development Plans for Tropospheric Winds Laser Transmitters

Laser Type

- Coherent Detection Lidar
  - 2.05 µm transmitter , injection-seeded
  - Frequency-agile LO (CW, 20 mW)
  - 0.5 J at 10-20 Hz, with conductive cooling
  - 2 MHz linewidth
  - 150-300 nsec pulsewidth
  - WPE 2%, 3 years lifetime
- Direct Detection Lidar
  - 355 nm transmitter (Nd laser, frequency tripled)
  - 300-500 mJ @ 100 Hz
  - 250 MHz (0.1 pm) linewidth
  - > 5 nsec pulsewidth
  - WPE 2%, 3 years lifetime

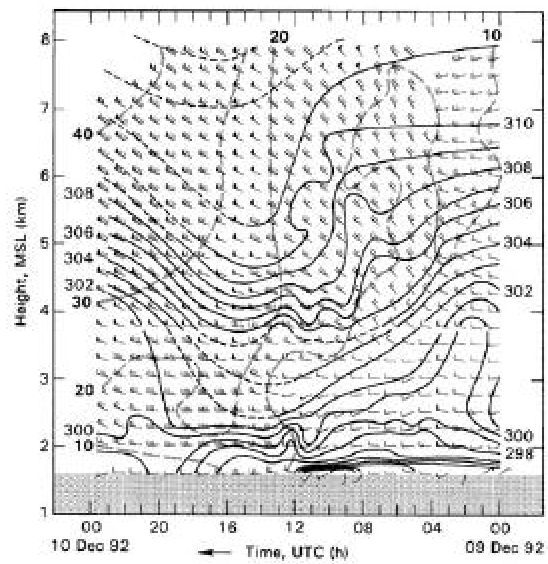


Justification

•Enables high vertical resolution profiling of tropospheric wind fields, with potential for cross-track horizontal resolution of 100-200 km in separate tracks or swath on either side of sub-orbital track

Top-Level Development Schedule

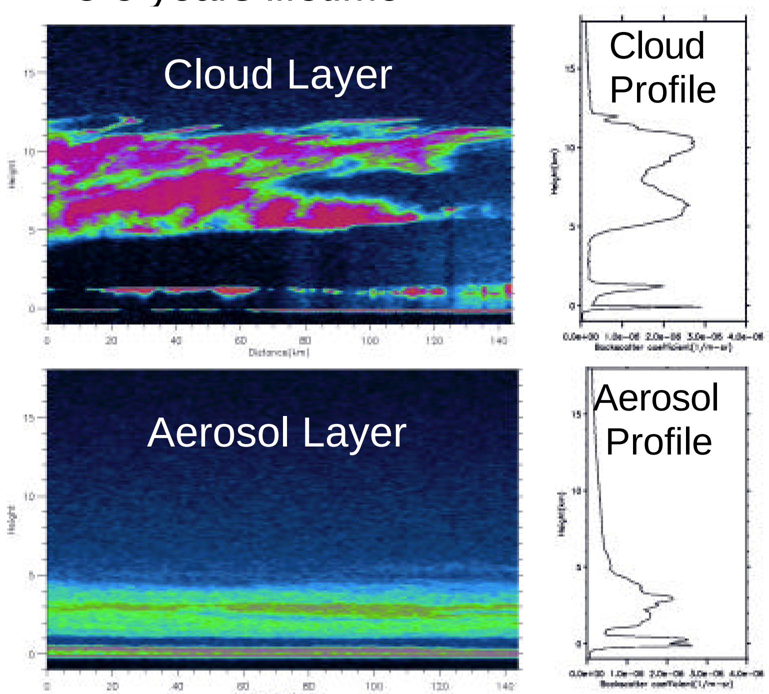
- Component development 2002
- Brassboard 2002-2003
- Engineering Model 2003-2004



Development Plans for Cloud and Aerosol Laser Transmitter

Laser Type

- Nd:YAG
    - Single-mode
    - Narrow frequency
- <5 pm linewidth
- > 100 Hz PRF,
- 5-50 Watts Output
- Conductive cooling
- 7% WPE
- 3-5 years lifetime



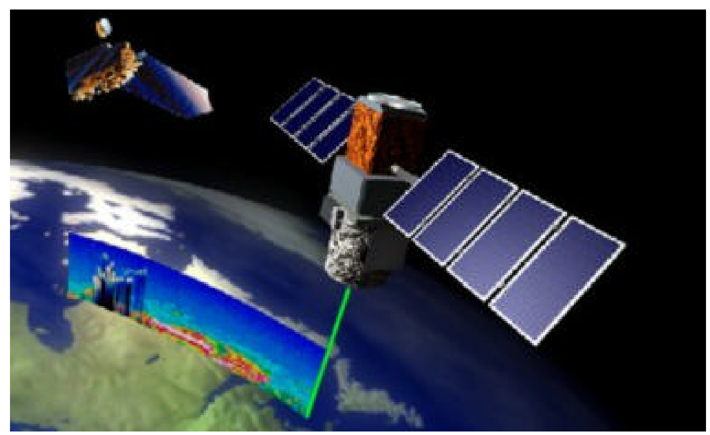
Justification

•Enables cross-track scanning backscatter lidar
- Mapping cloud profiles
- Mapping aerosol profiles

•Produces distributions with high vertical and horizontal resolution for clouds and aerosols of radiation forcing significance

Top-Level Development and Schedule

- Component development 2002-2003
- Brassboard 2003-2004
- Engineering Model 2004-2006



Workshop Summary Comments

- Most pressing need is support for brassboard and engineering model development of lasers for science-driven mission types
  - Risk reduction and reliability enhancement needed for future space lidars;
  - Leverage commercial technology development to extent possible;
  - Proposals for these developments require science requirement justification and accompanying lidar system performance modeling;
  - Improvements in realism of performance modeling require increased NASA investments in RTOP tasks addressing atmospheric measurements and characterization , and airborne instrument measurements.

- Establish/maintain NASA core competency in critical areas
  - Requires ongoing efforts to maintain critical personnel skills and modern laboratory facilities/equipment, coupled with vigorous recruitment of new talent in laser physics and engineering as well as e.g., contamination control, thermal design, radiation tolerances
  - Pump diode technology is a key requirement for which an inter-governmental action plan should be developed

- Fund specific technology needs which enable improved laser capabilities
  - Refer to listings from previous workshops

Further Comments on Laser Technology Development

- High-power, high-energy, space-based lasers are “one-of-a-kind”
  - Large non-recurring engineering costs and large R & D costs
  - NASA must leverage commercial technology to largest extend, but must develop in house capabilities to drive technology in directions unique to the civilian government sector
- Focused research towards enhancing laser efficiency and environmental robustness
- Commercial sector is increasingly uninterested in developing technology for U.S. government problems
- Targeted funding for space-based ““one-of-a-kind” high-energy lasers
- Directed core competency funding to NASA Centers engaged in laser research
- Integrated NASA strategy for developing component level and sub-system level technologies for future missions
- Foster technical alliance between NASA Centers, USAF, NOAA, DOE, NSF for the space-based laser technologies
- Develop, demonstrate and validate Engineering Model before mission award
- Parallel funding of core basic research, modeling, and laser materials development
- Yearly investment of $5 M towards space-based laser diode development, high damage threshold optics, conduction-cooled technologies, and radiation hardened component development
- Periodic review and assessment of laser technology plans and funding needs